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Color Matters: A Preliminary Assessment of Indoor Surface Colors on Visual Comfort, Thermal Comfort, and Air Quality

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Abstract

Indoor environmental quality significantly affects human perceptions of comfort and well-being due to the fact that most daily activities are spent indoors. However, surface colors are generally considered to be aesthetic choices rather than environmental factors. The purpose of this research is to assess the effect of surface colors on visual comfort, thermal intent, and plant-supportive lighting conditions. This study uses a controlled experimental method and four easily interpretable parameters: surface reflectance (albedo), illuminance, correlated color temperature, and photosynthetic photon flux density. The experiment uses a miniature enclosed chamber to standardize the geometry and lighting conditions to test a set of carefully chosen printed and painted color surfaces. The lighting parameters were directly measured using consumer-level spectral and illuminance meters. The surface reflectance parameter is estimated to be red, green, and blue color codes. The novelty of this research is that it provides a preliminary screening method that can convert color choice into quantifiable implications on indoor environments, with clear assumptions and limitations. The results can be used to inform design decisions that link color choice to specific task-oriented lighting requirements, climate-oriented thermal intent (cooler vs. warmer), and plant-rich interior environments.

Keywords: surface color; indoor environmental quality (IEQ); visual comfort; thermal comfort; air quality performance

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1. Introduction

1.1. General Background

According to the ASHRAE guidelines [1], individuals spend 80–90% of their daily time indoors, engaging in various activities, such as working, reading, and resting, all of which depend on adequate light. Light plays multiple roles in indoor environments: it provides necessary illumination (visual comfort), generates warmth (thermal comfort), and supports plant growth, which can enhance air circulation and quality [2]. Owing to these diverse functions, it is crucial to manage indoor environmental conditions to meet the occupants' specific needs. This can be achieved by assessing key indoor environmental quality (IEQ) parameters, including visual comfort, thermal comfort, and indoor air quality (IAQ) [3,4]. IAQ is also affected by contaminant buildup when indoor emission rates exceed

removal rates by ventilation and filtration, which can influence perceived safety, health, and occupant satisfaction. In the current study, IAQ is not evaluated by direct indoor pollutant concentration measurement; rather, plant-related air quality potential is explained by using plant-supportive lighting as an indirect measure.

The effect of IAQ on occupants is building type- and use-pattern-dependent. Offices, for instance, may exhibit different exposure dynamic and perceived satisfaction response patterns influenced by real-time occupancy effects [5], whereas houses and small apartments may be characterized by different source and removal patterns influenced by mechanical exhaust operation [6]. These differences may also be influenced by ventilation system arrangement and control; in variable air volume (VAV) systems, variations in airflow and air distribution may influence contaminant removal and hygiene conditions, prompting air terminal and air distribution-level design and control [7].

Assessment of IEQ parameters can generally be conducted by measuring the light reflection levels on room surfaces, such as walls, floors, and ceilings. For tasks such as reading, high levels of light are essential, making surfaces with high reflectance ideal for visual comfort enhancement [8]. Conversely, in cold environments, maintaining warmth conditions is a priority, and surfaces with higher absorption rates are more suitable as people can retain heat from sunlight [9]. The reflective and absorptive properties of a surface can be quantified using albedo, which measures the percentage of reflected light based on surface color [10]. A higher albedo indicates greater reflectance, whereas a lower albedo corresponds to increased absorption [11]. Calculating albedo values for each IEQ parameter makes it possible to determine the optimal surface colors for various activities and environmental conditions. This approach enables the development of indoor surface color guidelines that optimize IEQ performance, aiding architects and designers in selecting materials consistent with specific functional requirements.

This study provides indoor surface color guidelines, which can help architects and interior designers select appropriate surface materials and colors (Figure 1). By aligning these aspects with specific activities, the functional performance of indoor spaces can be markedly enhanced. This approach enables the creation of more effective design strategies that meet the diverse needs of occupants. Furthermore, optimizing the use of natural light for illumination and heating contributes to energy-efficient practices, reducing the reliance on artificial lighting and heating systems, which in turn lowers energy consumption and costs. In addition, this study may inform the development of standards and policies related to IEQ in building design, thereby promoting best practices and regulations that foster healthier and more sustainable indoor environments.

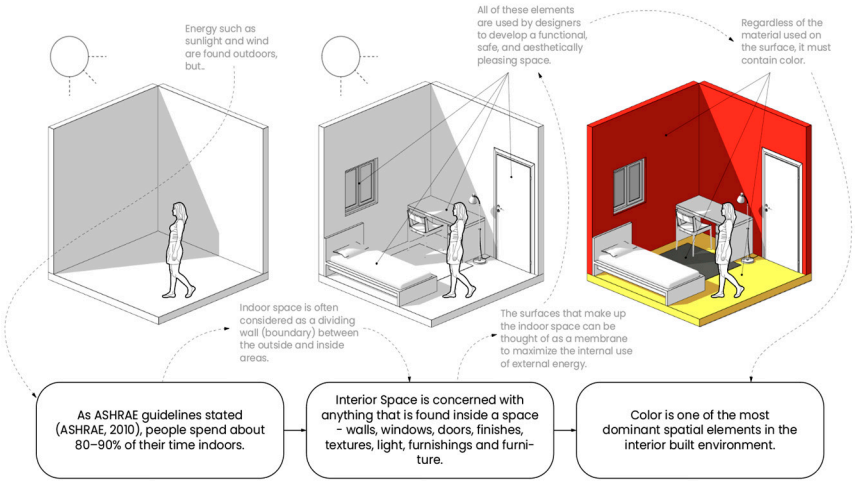


Figure 1. Visualization of light reflectance and surface color in indoor environments.

Proposed Novelty and Contributions (to insert at the end of Introduction/LR):

- Proxy-based screening framework for indoor surface color selection under controlled lighting. This study proposes a practical, repeatable workflow to compare surface-color alternatives using consistent illumination and device-based measurements, enabling early-stage screening before full-scale testing.
- RGB-derived reflectance proxy with illuminance normalization. We implement an RGB-based reflectance index (reported as "apparent albedo proxy") with an intensity correction factor to reduce bias from minor lighting or capture variability, enabling relative comparison across color samples.
- Transparent re-scoping of IEQ claims to proxy indicators. Visual and thermal interpretations are explicitly framed as proxy outcomes derived from photometric and colorimetric measurements, and limitations for real-room transferability are formally stated to guide future validation.

1.2. Literature Studies

1.2.1. Albedo

Albedo refers to the reflective capacity of a surface, particularly how much incident sunlight is reflected [12]. Derived from the Latin term for "whiteness" [13], albedo quantifies the ratio of reflected sunlight to the total amount of incoming sunlight [12]. Surfaces with a higher albedo reflect a greater proportion of light, whereas those with a lower albedo absorb more. Albedo is a dimensionless quantity ranging between 0 and 1, representing the reflectivity of a surface. A value of 0 indicates a "perfect absorber," meaning the surface absorbs the entire incoming energy, whereas a value of 1 denotes a "perfect reflector," reflecting the entire incoming energy [13].

Aside from the material properties, surface color considerably influences albedo. Darker surfaces tend to absorb more sunlight, resulting in lower albedo, whereas lighter surfaces reflect more light, yielding higher albedo values [14]. The albedo of a color can be determined using the equation outlined in Solar Geometry in Performance of the Built Environment [15]. Albedo can also be quantified based on a color's red, green, and blue (RGB) values, with each channel ranging from 0 to 255. For example, black is represented by RGB (0, 0, 0), where all color channels are turned off, whereas white is represented by RGB (255, 255, 255), where all channels are fully activated. Primary colors are defined as red (255, 0, 0), green (0, 255, 0), and blue (0, 0, 255) [16]. By combining these primary colors, tertiary colors are produced, such as purple, which has an RGB value of (147, 112, 219), indicating that red, green, and blue components have the values of 147, 112, and 219, respectively. These RGB values can be used to calculate the albedo of a given color.

However, RGB values do not represent true spectral reflectance because they are illuminant- and device-dependent and do not uniquely define wavelength-dependent reflectance [17,18]. In this study, the formulation based on the use of RGB values is adopted for its apparent reflectance under constant illumination and geometry for comparative purposes rather than true spectral or solar reflectance values [19].

The equation for calculating the RGB-derived reflectance proxy, as reported in Solar Geometry in Performance of the Built Environment [15], is shown in Equation (1):

$$Alb = \left[\frac{\sqrt{\left(\frac{R^2+G^2+B^2}{3} \right)}}{255} \right] I_c \quad (1)$$

Alb is the RGB-derived reflectance proxy (dimensionless, 0–1); *R*, *G*, and *B* are the red, green, and blue channel values (0–255); and I_c is an intensity-correction factor in the

original formulation. In Equation (1), I_c represents an intensity correction factor. Because all measurements were conducted under identical lamp settings and fixed geometry, I_c was held constant and set to 1 for all tested colors in this study.

Albedo describes the fraction of incident radiation reflected by a surface and is commonly represented as a unitless value between 0 and 1. In indoor environments, surface reflectance characteristics can influence visual comfort by shaping luminance distribution, perceived brightness, and glare potential. Albedo-related absorption may also influence thermal comfort indirectly by affecting radiant heat exchange and contributing to the mean radiant temperature of the surrounding environment. In this study, albedo is used as a practical comparative proxy to rank the relative lightness of the tested colors under controlled lighting conditions. The albedo values are estimated from sRGB (RGB) codes using Equation (1) adapted from [15]. However, RGB-based values are not interpreted as true spectral or solar reflectance because RGB is illumination-dependent and does not uniquely define spectral reflectance. Therefore, albedo is interpreted here as a relative indicator and is discussed together with directly measured lighting parameters (illuminance and correlated color temperature). Plant-related outcomes are discussed primarily through PPFD (PAR availability) rather than albedo alone [20–22]

This study did not measure spectral reflectance using a spectrophotometer. Because RGB encodings do not uniquely represent spectral reflectance and can vary with the illuminant spectral power distribution and device response, the RGB-derived reflectance proxy interpreted as an approximate comparative indicator within our controlled setup. Future work should incorporate spectrometric measurements following standardized practices for object-color evaluation to enable stronger physical interpretations [20,21,23].

1.2.2. IEQ Parameters

IEQ plays a vital role in the design of sustainable buildings, as it directly influences the health and well-being of occupants [24]. IEQ refers to the indoor conditions affecting human comfort, including factors such as lighting, air quality, and humidity levels [25]. Alhorr et al. [26] reported that there are four key parameters of IEQ: visual comfort, thermal comfort, acoustic comfort, and air quality. However, this study focuses only on visual comfort, thermal comfort, and air quality. This is because acoustics predominantly concern the density of material particles and perception, which exhibit less correlation with the characteristics of color performance [27].

- Visual Comfort

Dolnikova and Katunsky [28] defined visual comfort as a subjective response to the quantity and quality of light in a given space at a specific time. Achieving visual comfort depends on the ability to control ambient light levels to avoid discomfort caused by insufficient or excessive lighting. It is necessary to adjust the standard of light reflectance value on surfaces as a reflectance value that is too high will cause glare, whereas a low reflectance value will result in low lighting [29]. The light reflectance on a surface is the ratio of the light flux reflected by an object (with or without diffusion) to the flux it receives [30]. According to the standards set by The Energy and Resources Institute [31], lighting needs are classified based on albedo values for different surfaces, such as ceilings (0.7–0.9) and floors (0.2–0.4). These standards also account for the type of space, whether office or residential.

Beyond reflectance, visual comfort can also be evaluated by the illuminance value of the light produced by a surface color. According to the Handbook of Lighting Design [32], illuminance measures the density of light flux, indicating the amount of luminous flux falling on a given surface area. Higher illuminance values correspond to brighter spaces. The “Guidelines for Optimum Visual Comfort Derived from Key Performance Parameters”

provide specific standards for illuminance and light reflectance (albedo) to ensure optimal visual comfort.

- Thermal Comfort

The BS EN ISO 7730 British Standards Institution [33] is an international standard that provides guidelines for evaluating thermal comfort in buildings. It defines thermal comfort as the mental state in which an individual feels satisfied with the thermal environment, which means people do not feel too hot or too cold. The Health and Safety Executive [34] highlights the importance of thermal comfort, as discomfort caused by feeling too hot or cold can result in symptoms such as excessive fluid intake, frequent changes in posture, and increased physical movement, all of which can reduce productivity.

Several factors influence thermal comfort within a space, one of which is radiant temperature [35,36]. Radiant temperature refers to the heat transferred via electromagnetic radiation, which occurs when an object or surface is warmer than the surrounding air [37]. The thermal energy from the object or surface radiates into the room, increasing the ambient temperature [38]. Therefore, the management of the heat absorption of light on surfaces is crucial to ensure that the radiant temperature is consistent with human thermal comfort needs [39]. As shown in Appendix A Figure A1, lower albedo values correspond to higher heat absorption, resulting in increased radiant temperatures.

Several studies have investigated the association between surface color and thermal effects. For example, The Effect of Surface Color on the Absorption of Solar Radiation [40] examined the heat absorption characteristics of various colors, including black, green, red, purple, yellow, pink, blue, and white. The study found that black surfaces exhibited a high heat absorption capacity, as demonstrated by rapid temperature increases, whereas lighter colors exerted the opposite effect [41,42]. This study highlights the significant role that surface color plays in temperature regulation.

Another study from Interactions Between The Perception of Light and Temperature [43] identified additional factors that may influence the thermal effects of color, such as correlated color temperature (CCT). In this regard, CCT is a measure of the perceived color quality of a light source, ranging from bluish white at higher CCT values to yellowish red at lower CCT values [44]. Although CCT does not directly alter the actual room temperature, it affects perceived thermal comfort through the "chill effect," a cold sensation that can induce shivering. The study found that in cold environments, higher CCT values (bluish-white light) lead to greater shivering response compared with lower CCT values (yellowish-red light). However, this effect was not observed in warmer environments, where thermal comfort remained largely unaffected by CCT.

- Plant-Supportive Lighting (PPFD)

One indicator of good air quality is the concentration of oxygen in the air, which must meet a minimum standard of 19.5% oxygen content [45]. Generally, higher oxygen levels indicate better air quality, provided that they do not exceed the maximum safety limit [46]. One way to increase indoor oxygen levels is through the use of plants, which produce oxygen via photosynthesis [47]. Plants rely on chlorophyll pigments to absorb the light necessary for photosynthesis [48,49]. Chloroplasts, which house the chlorophyll molecules, absorb light mainly in the blue-violet and red wavelengths while reflecting green light [50].

The light available for photosynthesis is commonly described by photosynthetic photon flux density (PPFD) within the 400–700 nm range. Because photometric quantities such as illuminance (lux) are based on human visual sensitivity, lux-to-PPFD conversion requires knowledge of the light spectrum and is therefore spectrum-dependent PPFD measures the number of photons in the 400–700 nm wavelength range (the photosynthetically active radiation) that reach a plant's surface per unit time, expressed in $\mu mol/m^2/s$ [51].

PPFD provides a measure of how much light is available for plants to carry out photosynthesis. The higher the PPFD in a given space, the greater the rate of photosynthesis in plants [52]. Although different plants have varying PPFD requirements, there are general classifications [53]. Low-light (shade) plants typically require at least 230 μmol/m^2/s of PPFD, whereas high-light (shade-intolerant) plants require at least 350 μmol/m^2/s, with a maximum PPFD threshold of 700 μmol/m^2/s [54].

Although previous studies and guidelines have acknowledged the importance of the color and reflectance of the interior surface, the current practice of early-stage design lacks an effective method of comparing color alternatives under controlled conditions with the help of a set of quantitative indicators. The existing methods are mostly qualitative, limited to one dimension, or require full-scale tests along with the simulation process, which are not easily applicable during the early stages of design. This is the motivation behind the development of a controlled measurement-based screening method that can perform fair cross-color comparison while keeping the distinction between the measured variables and interpretations.

The novelty of this work is threefold: the development of a repeatable screening process for the selection of indoor surface color under fixed lighting and geometry, which can perform cross-color comparison with the help of device measurement; the implementation of the RGB-derived reflectance proxy, also known as the apparent albedo proxy, with the help of an intensity correction factor. Third, it explicitly re-scopes interpretations of indoor environmental quality to measured photometric and colorimetric variables (illuminance and correlated color temperature) and well-defined proxy indicators (including illuminance-based estimation of plant-supportive lighting) with restrictions on real-room transferability explicitly stated to inform sound interpretation and future full-scale validation.

1.2.3. Research Gap from Existing Studies

The literature review shows that numerous studies have investigated the light reflection and absorption properties of surface colors and their physical effects. However, their investigations remain fragmented and lack cohesive application to indoor activities. A more comprehensive approach is needed to bridge the gap between these findings and practical use. Key metrics, such as albedo and illuminance, are useful for understanding light intensity and its impact on visual comfort. In addition, albedo and CCT values influence radiant temperature and thermal comfort, whereas PPFD affects the photosynthetic rate of indoor plants, thereby contributing to air quality.

Visual comfort, thermal comfort, and air quality are critical components of IEQ and play a pivotal role in enhancing the comfort of daily indoor activities. This study can further inform the development of guidelines for optimizing surface colors in indoor environments, tailored to the specific context and activities within a space. This approach promotes sustainable practices, particularly in terms of IEQ health, well-being, and energy efficiency. This study aimed to address these gaps by investigating the integration of albedo, CCT, and PPFD values in relation to visual comfort, thermal comfort, and air quality. As such, we can develop practical guidelines for optimizing surface colors in indoor environments to enhance IEQ and support sustainable, activity-specific indoor design.

2. Methods

The proposed method comprises three stages: (1) controlled chamber setup and surface preparation, (2) measurement of lighting and indoor environmental variables, and (3) dataset processing and analysis, as summarized in Figure 2. In this workflow, the RGB-based albedo is treated as an RGB-derived reflectance proxy for relative comparison, and PPFD is estimated from photometric measurements under fixed lamp conditions.

These quantities are used to support comparative interpretation across surface colors, rather than to directly represent true spectral reflectance, radiant absorptance, or absolute photosynthetic photon availability [55–57].

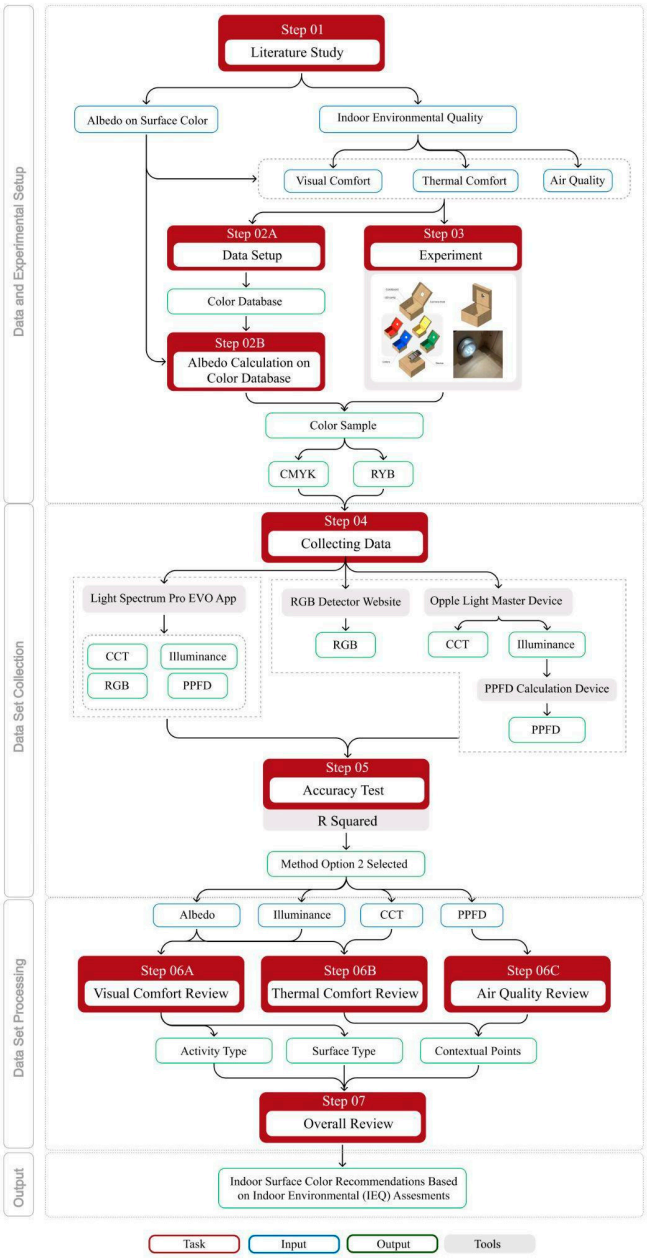


Figure 2. Methodology Diagram.

Figure 2 summarizes the analysis sequence used in this study. Stage 1 (Data and Experimental Setup) covers the miniature chamber configuration and the preparation of surface color samples to ensure consistent geometry and exposure. Stage 2 (Data set Collection and Measurements) captures the primary measured variables, including illuminance, correlated color temperature, and other lighting descriptors, along with indoor environmental readings collected under the same lamp setting and fixed measurement positions. Stage 3 (Data Processing and Analysis) converts the collected dataset into analysis-ready features, including an RGB-derived reflectance proxy (for comparative ranking) and an estimated PPFD metric (used as a relative indicator under fixed lamp

conditions), followed by statistical comparisons to identify how surface colors relate to visual, thermal, and plant-related IEQ pathways.

2.1. Data and Experimental Setup

This experiment was designed to determine the effect of various indoor surface colors on indoor environmental quality parameters, particularly visual comfort, thermal comfort, and indoor air quality. The design of the experiment is based on a miniature indoor model where the surface colors are varied while keeping the lighting conditions constant, thus the differences observed are only due to the varied surface colors. The primary data sources used in this research are the data measured by devices and the recorded color inputs, which were recorded by the authors while conducting the experiment. No restricted data sources were used, only references that are publicly available for post-processing, such as conversion references used to calculate plant-supportive lighting, which is allowed for academic purposes only and is used transparently by the researcher. The miniature indoor chamber, which is 22 × 22 × 12 cm in size, is used only to standardize the geometry and lighting conditions for the purpose of relative comparison of various surface colors, and not to mimic the actual lighting conditions found in a room, although interreflections are present in the miniature room.

2.1.1. Color Sample Source

The color samples were sourced from the Back4app Color Database, accessible at https://www.back4app.com/database/back4app/rgb-color-codes-and-names/color-dataset-via-api (accessed on 6 June 2023) [58]. Each sample includes the color name and its corresponding RGB code. The data were processed by visually displaying each color in rows, enabling the identification and confirmation of its appearance based on the given RGB code (Appendix A Figure A2).

2.1.2. Color Data Collection Method

The three key aspects of IEQ—visual comfort, thermal comfort, and air quality—are influenced by the light reflection properties of surfaces. To evaluate these properties, it is crucial to determine the albedo value of each color code, allowing for the ranking of colors based on their light-reflecting capabilities. Albedo values can be calculated using Equation (1). As an example of manual calculation, consider the color dark spring green with RGB values of (23, 114, 69). The albedo calculation for this color is computed as shown in Appendix A Figure A3. By inputting the equation into a Google Sheet, the albedo values for each color can be automatically calculated, thereby streamlining the process.

2.1.3. Experimental Room Setup

This experiment aimed to evaluate the impact of different indoor surface colors on IEQ parameters, particularly visual comfort, thermal comfort, and air quality. To achieve controlled and repeatable measurements, we constructed a miniature enclosed chamber (22 cm × 22 cm × 12 cm) with interchangeable interior surface-color linings (Figure 3). The chamber was designed as a controlled optical test environment, allowing the study to isolate the relative influence of surface color on measured light-related IEQ indicators under the same geometry and lighting configuration. This approach is consistent with the use of physical scale models and controlled chambers in lighting and daylighting research, where the primary goal is to obtain comparative performance differences under standardized conditions rather than to fully replicate all real-room boundary conditions [59,60]. The surface colors were applied using removable lining paper samples.

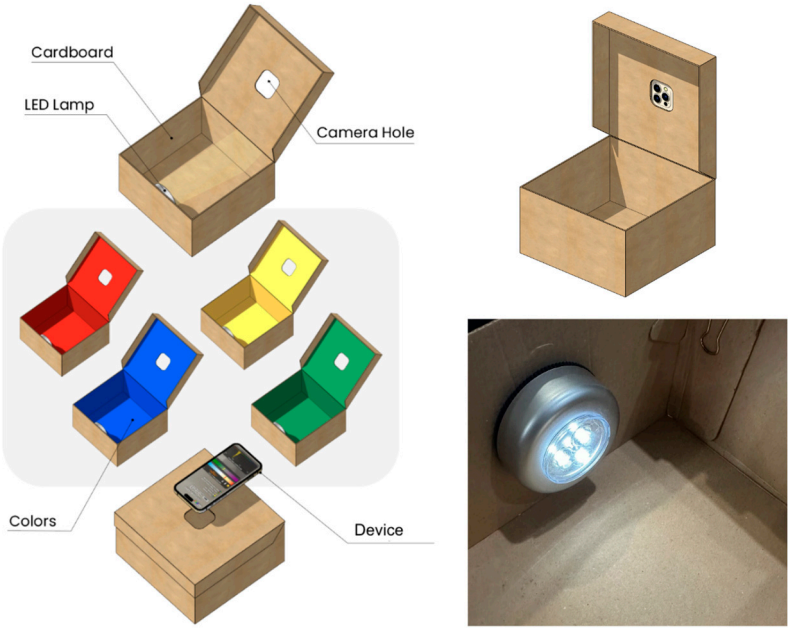


Figure 3. Experimental setup for evaluating indoor surface colors on IEQ parameters.

A circular LED stick touch lamp with 7 cm diameter (PT Rumah Mebel Nusantara (IKEA Indonesia), Kota Tangerang, Banten, Indonesia) served as the light source and was operated at a fixed setting to maintain consistent illumination while surface colors were varied. A circular aperture on the top panel accommodated the data-collection devices; iPhone 14 Pro rear camera (Apple Inc., Cupertino, CA, USA) and Opple Light Master (OPPLE Indonesia, North Jakarta, Indonesia) was fitted to limit stray ambient light entering the chamber, preserving the controlled lighting condition inside the box. This approach is consistent with physical scale modeling practices used for controlled lighting and daylighting evaluation [59,60].

The miniature enclosure was designed for within-setup comparison across color conditions under fixed geometry and lamp configuration. As a consequence, the setup does not represent full-scale effects related to thermal mass, air exchange, or occupant-level view geometry; transferability to full-room thermal comfort conditions requires additional validation (e.g., full-scale measurements or calibrated simulation) [60,61].

2.1.4. Sample-Selection Process

The selection of color samples is listed based on the albedo value ranking from the color database, accessible at https://docs.google.com/spreadsheets/d/1AZ7tfA-kixhoR3A0NHGmT8Tv9NoYOpdLPyPD_E4HOHg/edit?usp=sharing (accessed on 28 May 2023). This method enables examination of how different albedo reflectance levels affect IEQ parameters, including visual comfort, thermal comfort, and air quality. This study then selected 10 samples from a total of 957 colors in the database. The selection process followed a sequential pattern, with every 106th color being chosen. The final list of the 10 selected samples is presented in Figure 4.

The RGB codes were converted into two surface coloring models: printed coloring cyan, magenta, yellow, and key (CMYK) and painted coloring red, yellow, and blue (RYB) (Appendix A Table A1). The CMYK color model (cyan, magenta, yellow, black) was used for printed materials, such as wallpaper and vinyl. By contrast, the RYB color model was applied to pigment-based paints. The 10 preselected samples were divided into these two coloring models, CMYK and RYB—resulting in a total of 20 samples for the experiment.

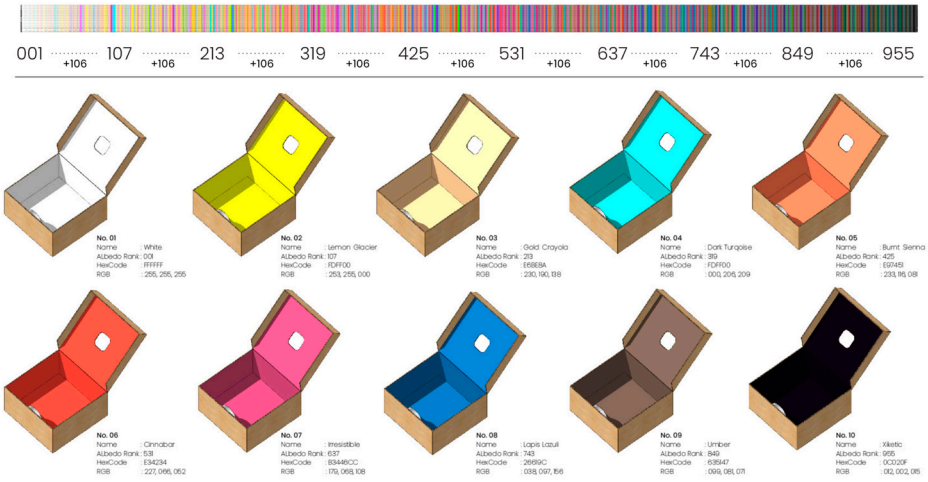


Figure 4. Selected color samples based on albedo rank.

2.2. Dataset Collection

2.2.1. Light Spectrum Pro EVO

There were two options for data collection in this experiment (Appendix A Figure A4). The first option involved the utilization of the Light Spectrum Pro EVO 2023 version 4.3.1 application as the primary tool, whereas the second one involved the use of the Opple Light Master device. The Light Spectrum Pro EVO app, which is available on App Store [62], measures various lighting parameters without the need for specialized equipment. It provides readings for color temperature in Kelvin, which is useful for assessing thermal comfort and measuring light intensity. In addition, it captures wavelength spectrum and PPFD values, which are essential for assessing air quality by analyzing the rate of photosynthesis in plants. The app has a margin of error of 2–8% compared with professional-grade tools, making it a reliable option for the experiment.

2.2.2. Opple Light Master

The second method of data collection involved the use of the Opple Light Master device. According to App Store [63], the Opple Light Master device functions as a lux meter, offering features such as CCT, UV, and XY coordinates. One of its key advantages is the specialized sensor that accurately detects CCT and illuminance values. The device connects to the Light Master app via Bluetooth, which is installed on a smartphone. For data collection, the device was placed on top of the box with its sensor facing the hole to measure illuminance and CCT. The measured values were displayed in real-time through the smartphone app.

However, the Opple Light Master device has a limitation—it cannot detect RGB and PPFD values. To address this, additional resources or tools were needed to supplement the missing data. The first supporting tool used to detect dominant RGB values was an online platform accessible at Find Dominant Colors in JPG Images (Appendix A Figure A5). The detailed method for identifying dominant RGB values is provided in Appendix A Figure A8. To ensure comprehensive data collection, this process was repeated for 20 different samples—10 CMYK samples and 10 RYB samples—allowing for the extraction of the dominant RGB code for each color sample. Appendix A Figure A9 presents the documentation of illuminance and CCT measurements using the Opple Light Master device.

PPFD values were then calculated from the measured illuminance and the type of light source using the "Convert Lux to PPFD" online calculator on the Waveform Lighting website [64], and the detailed conversion procedure is provided in Appendix A Figure A6.

The full procedure for converting Lux to PPFD is provided in Appendix A Figure A10. Because illuminance (lux) is weighted to the human visual response and the conversion to PPFD depends on the spectral power distribution (SPD), the resulting PPFD values interpreted as approximate. In addition, reflected light from colored surfaces may alter the effective spectrum reaching the sensor, which can introduce additional uncertainty when using any fixed-factor conversion. Therefore, PPFD in this study is used primarily as a relative comparison indicator across surface colors under controlled conditions, rather than an absolute PPFD measurement [65,66].

A high color rendering index (CRI) LED was used to improve the fidelity of perceived surface colors in the recorded images, helping the captured colors remain consistent across samples [67]. However, a high CRI does not fully eliminate spectral dependence in lux-to-PPFD conversion; thus, PPFD is still treated as an approximate, comparative indicator as stated above [65,66].

Appendix A Tables A7 and A8 show that the accuracy values produced by the Opple Light Master device and its supporting website are higher compared with those obtained from the Light Spectrum Pro EVO app. A more detailed RGB value accuracy checking process across devices is presented in Appendix A Table A8. The overall measurement accuracy comparison for RGB, illuminance, CCT, and PPFD is provided in Appendix A Table A8. This indicates that the data collection method involving the use of the Opple Light Master device and its supporting resources is more reliable. Documentation of RGB, illuminance, CCT, and PPFD data capture using the Light Spectrum Pro EVO app can be found in Appendix A Figure A7. Consequently, the data used for processing in the subsequent chapter were sourced from the Opple Light Master device and its associated website.

2.3. Data Processing Method

2.3.1. Visual Comfort

Based on lighting standards from The Energy and Resources Institute [31], ideal illuminance values were categorized by activity type. Different activities require varying lighting levels: tasks that require high concentration, such as studying, need higher illuminance (500–750–1000 lux), whereas more relaxing activities such as resting require lower lighting levels (50–75–100 lux). In addition, light reflection guidelines vary by the position of the surface within the room, with walls, ceilings, floors, and furniture each having their own reflection standards.

2.3.2. Thermal Comfort

High light absorption by a surface results in increased heat storage, which is then radiated into the room, raising the room temperature and affecting thermal comfort. In addition to radiant temperature, thermal perception also plays a crucial role in thermal comfort. This perception is influenced by the CCT value. According to a previous study [43], although CCT does not directly impact room temperature, it influences thermal sensations and comfort through the perception of cold. CCT exerts a significant effect in cooler environments, where higher CCT values (bluish-white light) increase the cold sensation, causing more shivering compared with lower CCT values (reddish-yellow light). The association between radiant temperature, CCT, and thermal comfort depends on the room's temperature or the climate in which it is situated.

2.3.3. PPFD Estimation (Lux-to-PPFD Conversion)

Indoor air quality (IAQ) is typically evaluated using pollutant-related indicators such as CO_2 concentration, volatile organic compounds (VOCs), and particulate matter (PM). Such IAQ variables are not quantified in this research. Rather, a plant-related mechanism is considered by reporting the photosynthetic photon flux density (PPFD, 400–700 nm) as a

proxy for plant-supportive light availability within the tested lighting system. PPFD was not directly measured by a quantum sensor. It was calculated from illuminance (lux) by an online lux to PPFD calculator with a constant lamp type, position, and geometry for all experiments (Appendix A Figure A10). As the lux to PPFD conversion is spectrum-dependent and surface colors can affect the spectrum reaching the sensor by reflected light, the calculated PPFD values are considered to be approximate. Therefore, PPFD is used as a relative indicator of PPFD among surface colors in the controlled environment, not as an absolute PPFD measurement or IAQ improvement.

3. Results and Discussion

Results are divided into three sections: a comparison of the different color samples, a comparison between the CMYK (printed) and RYB (painted) coloring techniques, and instruments that allow architects to select the appropriate colors based on the context's IEQ. The results are interpreted as comparative trends within the controlled miniature setup. The chamber geometry is appropriate for cross-color comparison but does not replicate full-scale room lighting dynamics or interreflection. Thermal mass effects are not measured; hence, the thermal-related results are discussed as a tendency of the absorption/reflectance under the lamp configuration rather than the full-scale temperature or mean radiant temperature.

3.1. Color Comparison Results

3.1.1. Visual Comfort

The albedo values from the 20 color samples were compared against the relevant standards, yielding varied results (detailed RGB-based albedo calculation results are provided in Appendix A Figure A11). Unlike the illuminance values, the albedo values encompassed all surface categories. The detailed results of this comparison are presented in Table 1.

Table 1. Detected RGB (LSP EVO and OLM) and Computed Albedo for CMYK and RYB Samples (authors' measurements). The surface-category reflectance ranges used for interpretation are based on ISO/CIE guidance [68].

No	Samples	Albedo	Office Space	Residential Space
1	Gold Crayola CMYK	0.86	Ceiling	Ceiling
2	Cinnabar CMYK	0.80	Ceiling, Walls	Ceiling
3	Irresistible CMYK	0.72	Ceiling, Walls	Ceiling
4	Burnt Sienna CMYK	0.69	Walls, Furniture	Ceiling
5	Lemon Glacier CMYK	0.67	Walls, Furniture	Ceiling
6	Dark Turquoise CMYK	0.67	Walls, Furniture	Ceiling
7	Lapis Lazuli CMYK	0.66	Walls, Furniture	Ceiling
8	White CMYK	0.64	Walls, Furniture	Ceiling
9	Umber CMYK	0.55	Walls, Furniture	Walls
10	Xiketic CMYK	0.47	Walls, Furniture	Walls
1	Burnt Sienna RYB	0.71	Ceiling, Walls	Ceiling
2	Gold Crayola RYB	0.68	Walls, Furniture	Ceiling
3	White RYB	0.66	Walls, Furniture	Ceiling
4	Cinnabar RYB	0.63	Walls, Furniture	Ceiling
5	Irresistible RYB	0.61	Walls, Furniture	Ceiling
6	Lemon Glacier RYB	0.60	Walls, Furniture	Ceiling, Walls
7	Dark Turquoise RYB	0.60	Walls, Furniture	Ceiling, Walls
8	Xiketic RYB	0.59	Walls, Furniture	Walls
9	Lapis Lazuli RYB	0.55	Walls, Furniture	Walls
10	Umber RYB	0.30	Floors, Furniture	Floors

The albedo values of each color are summarized in Figure 5 and grouped using recommended diffuse reflectance ranges for typical interior surfaces (ceiling: 0.7–0.9, walls:

0.5–0.8, floor: 0.2–0.6) to support interpretation in lighting design contexts [62]. Table 1 reports the measured color samples and computed albedo values used to generate Figure 5. However, it is noteworthy that these standards are limited to residential and office space categories. To generate Figure 5, the measured RGB values for each color sample (recorded using LSP EVO and validated using the OLM device under the fixed LED lighting condition) were converted into an albedo proxy using Equation (1). The resulting albedo values were then grouped according to recommended diffuse reflectance ranges for common interior surfaces (ceiling, walls, floor) to support interpretation in a lighting design context [68]. Table 1 reports the underlying measured samples and computed albedo values that are subsequently visualized and grouped in Figure 5.

User Requirements: Question 1B	Activies Group	Color Result	Albedo Value	Surface						
				Office				Residential		
				Ceiling	Walls	Floors	Furniture	Ceiling	Walls	Floors
				0.7–0.9	0.5–0.8	0.2–0.4	0.2–0.7	0.6–0.9	0.35–0.6	0.15–0.35
Is the room intended for office or residential use?	Group A	*You can use colors in group C (low illuminance) by lowering the light intensity in the room*	-	*Depends on the color*				*Depends on the color*		
	Group B	*You can use colors in group C (low illuminance) by lowering the light intensity in the room*	-	*Depends on the color*				*Depends on the color*		
	Group C	Umber RYB	0.30			✓	✓			✓
		Xiketic RYB	0.59		✓		✓		✓	
	Group D	Cinnabar CMYK	0.80	✓	✓			✓		
		Irresistible CMYK	0.72	✓	✓			✓		
		Lapis Lazuli CMYK	0.66		✓		✓	✓		
		Umber CMYK	0.55		✓		✓		✓	
		Xiketic CMYK	0.47		✓		✓		✓	
		Gold Crayola RYB	0.68		✓		✓	✓		
		Dark Turquoise RYB	0.60		✓		✓	✓	✓	
		Burnt Sienna RYB	0.71	✓	✓			✓		
		Cinnabar RYB	0.63		✓		✓	✓		
		Irresistible RYB	0.61		✓		✓	✓		
		Lapis Lazuli RYB	0.55		✓		✓		✓	
	Group E	White CMYK	0.64		✓		✓	✓		
		Lemon Glacier CMYK	0.67		✓		✓	✓		
		Gold Crayola CMYK	0.86	✓				✓		
		Dark Turquoise CMYK	0.67		✓		✓	✓		
		Burnt Sienna CMYK	0.69		✓		✓	✓		
		White RYB	0.66		✓		✓	✓		
		Lemon Glacier RYB	0.60		✓		✓	✓	✓	

Figure 5. Distribution of computed albedo values (Equation (1)) for tested color samples, grouped using ISO/CIE recommended diffuse reflectance ranges for typical interior surfaces (ceiling, walls, floor) [68].

The illuminance values from the 20 color samples were compared with activity-based illuminance standard groups (Appendix A Table A2). The results indicated that 2 color samples fell into Group C, 11 samples fell into Group D, and 7 samples exceeded 1000 lux—the upper limit of the illuminance values defined by the group divisions—therefore not fitting into any group. No color samples were classified into Group A or B. These findings indicate that the range of detected illuminance values is generally higher than the standard illuminance range specified for various activities.

Figure 6 classifies illuminance values based on IESNA activity standards, which define the lighting requirements for different activities. The color samples are grouped according to the required level of lighting. Group A represents illuminance levels of 50–75–100 lux, suitable for low-light activities. Group B covers values of 100–150–200 lux, whereas Group C includes a range of 200–300–500 lux, appropriate for moderate lighting needs. Group D represents the highest standard levels of 500–750–1000 lux, catering to activities requiring significant lighting. In addition, Group E was introduced to accommodate color samples that produced illuminance values above 1000 lux. All 20 color samples were classified according to these standards.

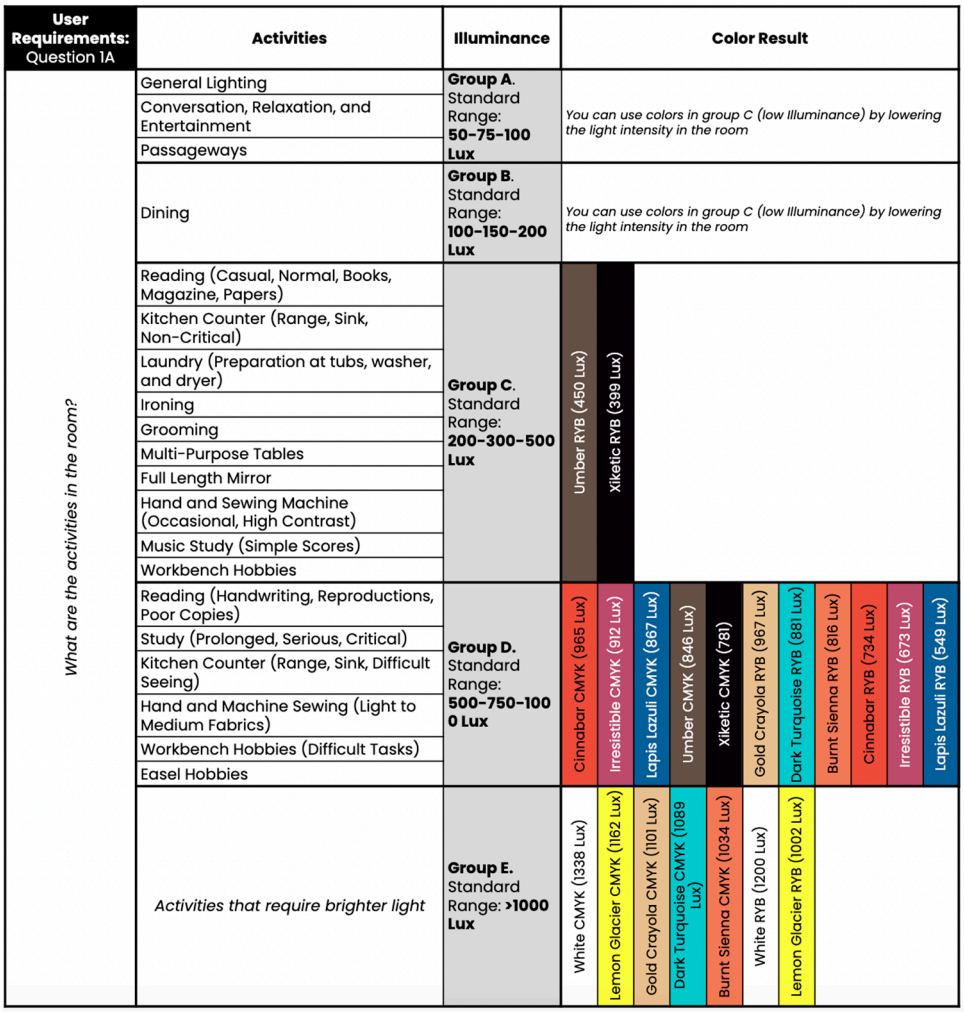


Figure 6. Classification of illuminance values based on IESNA activity standards.

3.1.2. Thermal Comfort (Proxy-Based Thermal Intent Ranking)

Thermal-related outcomes are presented as a climate-oriented thermal intent ranking based on relative absorption/reflectance tendency within the tested lamp configuration, rather than as a direct prediction of full-room thermal comfort, mean radiant temperature, or energy performance. This proxy does not represent measured heat transfer or validated comfort indices (air/radiant/operative temperature or PMV/PPD) It is provided as a relative screening result in the context of the test configuration only. The RGB-based apparent reflectance proxy is not a measurement of heat transfer or a validated thermal comfort index and is provided in the context of the test configuration only, in relation to other directly measured lighting parameters.

In a hot climate, a cooler thermal intent is related to a set of surfaces that have a higher relative reflectance tendency (i.e., a higher apparent albedo proxy). A points system is used to rank the apparent albedo proxy values, where the sample with the highest value receives the maximum points, and so on (Appendix A Table A3). The sample with the highest points is interpreted as the best color in terms of its support of a cooler thermal intent in the context of a hot climate.

In a cold climate, a warmer thermal intent is related to lower reflectance tendency (lower apparent albedo proxy) and lower correlated color temperature under the tested lighting condition. These two parameters are ranked and converted to points (Appendix A Table A4), where lower values are ranked with higher points. The sample

with the highest points is considered to be the most favorable color in relation to supporting a warmer thermal intent under cold climate assumptions.

The thermal proxy point calculations for cold climates indicate that Umber RYB is the best-performing color, with a total score of 18.5 points. Xiketic RYB ranks second, with a total score of 18 points, followed by Xiketic CMYK with 16.5 points. The lowest-ranked color is Gold Crayola CMYK, with a total score of 3 points, followed by Irresistible CMYK with 3.5 points and Cinnabar with 5 points.

For thermal-related interpretation in this research, the basis will be the apparent albedo proxy and correlated color temperature based on the tested lamp configuration. In each of the climate-oriented scenarios, hot or cold, these indicators are ranked and scored into corresponding points, as shown in Figure 7. In the tested configuration, higher apparent albedo proxy values represent a greater reflectance tendency, which will be used to represent a cooler thermal intent, while lower apparent albedo proxy values and lower correlated color temperature will be used to represent a warmer thermal intent.

User Requirements: Question 2	Activities Group	Color Result	Surface		Hot Climate Score
			Office	Resident	
Is the room in a hot or a cold climate? **hot climate**	Group A	You can use colors in group C (low illuminance) by lowering the light intensity in the room	-	-	-
	Group B	You can use colors in group C (low illuminance) by lowering the light intensity in the room	-	-	-
	Group C	Xiketic RYB	Walls, Furniture	Walls	5
		Umber RYB	Floors, Furniture	Floors	1
	Group D	Cinnabar CMYK	Ceiling, Walls	Ceiling	19
		Irresistible CMYK	Ceiling, Walls	Ceiling	18
		Burnt Sienna RYB	Ceiling, Walls	Ceiling	17
		Gold Crayola RYB	Walls, Furniture	Ceiling	15
		Lapis Lazuli CMYK	Walls, Furniture	Ceiling	11
		Cinnabar RYB	Walls, Furniture	Ceiling	9
		Irresistible RYB	Walls, Furniture	Ceiling	8
		Dark Turquoise RYB	Walls, Furniture	Ceiling, Walls	6
		Lapis Lazuli RYB	Walls, Furniture	Walls	4
		Umber CMYK	Walls, Furniture	Walls	3
		Xiketic CMYK	Walls, Furniture	Walls	2
	Group E	Gold Crayola CMYK	Ceiling	Ceiling	20
		Burnt Sienna CMYK	Walls, Furniture	Ceiling	16
		Lemon Glacier CMYK	Walls, Furniture	Ceiling	14
		Dark Turquoise CMYK	Walls, Furniture	Ceiling	13
		White RYB	Walls, Furniture	Ceiling	12
		White CMYK	Walls, Furniture	Ceiling	10
		Lemon Glacier RYB	Walls, Furniture	Ceiling, Walls	7

User Requirements: Question 2	Activities Group	Color Result	Surface		Cold Climate Score
			Office	Resident	
Is the room in a hot or a cold climate? **cold climate**	Group A	You can use colors in group C (low illuminance) by lowering the light intensity in the room	-	-	-
	Group B	You can use colors in group C (low illuminance) by lowering the light intensity in the room	-	-	-
	Group C	Umber RYB	Floors, Furniture	Floors	18.5
		Xiketic RYB	Walls, Furniture	Walls	18
	Group D	Xiketic CMYK	Walls, Furniture	Walls	16.5
		Irresistible RYB	Walls, Furniture	Ceiling	16
		Cinnabar RYB	Walls, Furniture	Ceiling	15
		Lapis Lazuli RYB	Walls, Furniture	Walls	13
		Dark Turquoise RYB	Walls, Furniture	Ceiling, Walls	12.5
		Lapis Lazuli CMYK	Walls, Furniture	Ceiling	10.5
		Umber CMYK	Walls, Furniture	Walls	10.5
		Gold Crayola RYB	Walls, Furniture	Ceiling	9.5
		Burnt Sienna RYB	Ceiling, Walls	Ceiling	9.5
		Cinnabar CMYK	Ceiling, Walls	Ceiling	5
		Irresistible CMYK	Ceiling, Walls	Ceiling	3.5
	Group E	Lemon Glacier RYB	Walls, Furniture	Ceiling, Walls	15
		Lemon Glacier CMYK	Walls, Furniture	Ceiling	9.5
		Dark Turquoise CMYK	Walls, Furniture	Ceiling	7.5
		White CMYK	Walls, Furniture	Ceiling	6
		Burnt Sienna CMYK	Walls, Furniture	Ceiling	5.5
		White RYB	Walls, Furniture	Ceiling	5.5
		Gold Crayola CMYK	Ceiling	Ceiling	3

Figure 7. Color sample suitability for hot- and cold-climate assumptions based on apparent albedo proxy and correlated color temperature (CCT) scores.

3.1.3. Plant-Supportive Lighting (Estimated PPFD)

The values of the estimated PPFD, as determined through the color samples used in the experiment, were found to be generally lower than the commonly cited values for indoor plant growth conditions. This is expected, as the PPFD values determined through the experiment are based on illuminance values using a standard approach, with a specific type of lamp, under a specific set of conditions with a limited enclosed space that could have an effect on the spectrum due to interreflections and surface colors. Thus, the values determined through this experiment are to be used as an estimation of PPFD values.

It is important to note that the PPFD is not an indicator of indoor air quality. Thus, as pollutant-based indicators of indoor air quality are not measured in this experiment, the values determined through the experiment are to be used as an estimation of plant light suitability to determine the effect of surface colors on the availability of photosynthetically active light [69].

According to the rankings of PPFD values, as shown in Appendix A Table A6, it was observed that the highest estimated value of PPFD was recorded for White CMYK (23.06 $\mu mol/m^2/s$), followed by White RYB (20.68 $\mu mol/m^2/s$) and Lemon Glacier CMYK (20.03 $\mu mol/m^2/s$). The lowest estimated PPFD values were observed for Xiketic RYB (6.88 $\mu mol/m^2/s$), Umber RYB (7.76 $\mu mol/m^2/s$), and Lapis Lazuli RYB (9.46 $\mu mol/m^2/s$).

3.2. Printed (CMYK) vs. Painted (RYB) Surface Comparison Result

The comparison between CMYK and RYB sample results is assessed using three key parameters: visual comfort (measured through illuminance and albedo), thermal comfort

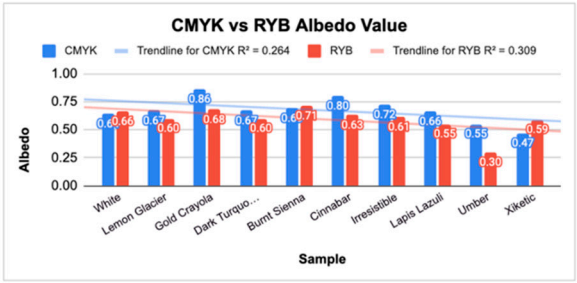
(assessed through albedo and CCT), and air-quality-related plant-light suitability (discussed using PPFD as a comparative proxy). Each value is reviewed to understand how CMYK and RYB samples perform in terms of IEQ enhancement across these parameters, and the results provide insights into the most effective color models for specific environmental needs.

3.2.1. Visual Comfort

In terms of albedo, the results indicate that there is no consistent trend in the bar chart as the values are not sequentially arranged (Figure 8). However, 8 out of the 10 color samples showed that the CMYK samples generally exhibited higher albedo values than the RYB samples. Higher albedo values indicate that more light is reflected by the surface, resulting in increased brightness in the room.

No	Sample	CMYK	RYB
1	White	1338	1200
2	Lemon Glacier	1162	1002
3	Gold Crayola	1101	967
4	Dark Turquoise	1089	881
5	Burnt Sienna	1034	816
6	Cinnabar	965	734
7	Irresistible	912	673
8	Lapis Lazuli	867	549
9	Umber	846	450
10	Xiketic	781	399

No	Sample	CMYK	RYB
1	White	0.64	0.66
2	Lemon Glacier	0.67	0.60
3	Gold Crayola	0.86	0.68
4	Dark Turquoise	0.67	0.60
5	Burnt Sienna	0.69	0.71
6	Cinnabar	0.80	0.63
7	Irresistible	0.72	0.61
8	Lapis Lazuli	0.66	0.55
9	Umber	0.55	0.30
10	Xiketic	0.47	0.59



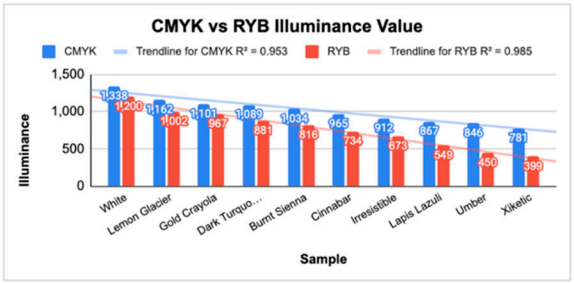


Figure 8. Comparison of CMYK and RYB samples based on albedo and illuminance values.

Similarly, the illuminance value graph in Figure 8 shows that the CMYK samples tended to generate higher illuminance values than the RYB samples, indicating that spaces with CMYK surfaces are typically brighter. In addition, the difference in illuminance values between CMYK samples was less pronounced, showing a more gradual slope in the bar chart. By contrast, the slope for the RYB samples was steeper, indicating greater variation in the illuminance values among the RYB samples. This indicates that the lighting levels in rooms using CMYK samples were more uniform and consistently bright, whereas the RYB samples resulted in more varied lighting conditions.

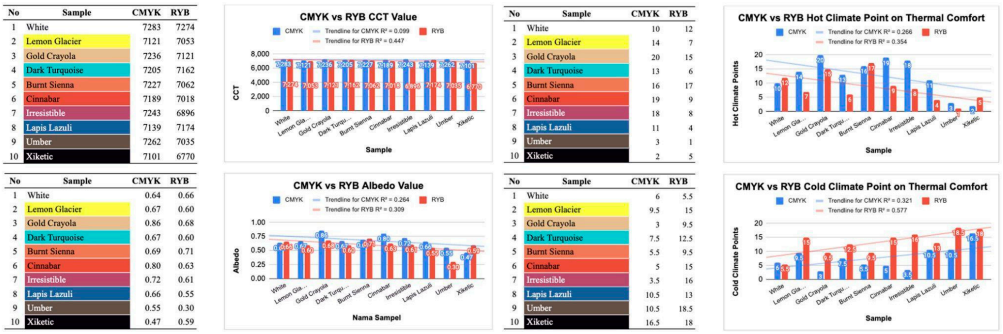
Visual performance in this study is characterized using illuminance and the apparent albedo proxy as first-order descriptors of brightness-related conditions within a controlled miniature enclosure under a fixed LED source. As shown in Figure 8, the CMYK samples generally produce higher illuminance and slightly higher apparent albedo proxy values than the RYB samples, indicating comparatively brighter conditions within the tested configuration. The CMYK set also shows a narrower spread of illuminance values, suggesting greater consistency across samples.

Illuminance and reflectance-related proxies, however, do not capture visual comfort comprehensively. Metrics and phenomena such as glare (e.g., UGR or luminance-based glare indices), luminance distribution, and visual adaptation were not evaluated. Accordingly, the results are reported as comparative brightness and reflectance trends under

controlled conditions rather than as a complete assessment of visual comfort in full-scale rooms [70].

3.2.2. Thermal Comfort (Proxy-Based Thermal Intent Ranking)

The graph in Figure 9 shows that the CCT values between the CMYK and RYB samples do not exhibit significant differences. The values remain relatively constant across the samples, with only slight variations. This indicates that the different colors used in a room do not drastically influence the CCT aspect. However, the CMYK samples consistently showed slightly higher CCT values than the RYB samples, indicating that the CMYK samples tended to reflect a slightly bluer light, resulting in a cooler perception of the room than the RYB samples.



No	Sample	CMYK	RYB
1	White	7283	7274
2	Lemon Glacier	7121	7053
3	Gold Crayola	7236	7121
4	Dark Turquoise	7205	7162
5	Burnt Sienna	7227	7062
6	Cinnabar	7189	7018
7	Irresistible	7243	6896
8	Lapis Lazuli	7139	7174
9	Umber	7262	7035
10	Xiketic	7101	6770

No	Sample	CMYK	RYB
1	White	0.64	0.66
2	Lemon Glacier	0.67	0.60
3	Gold Crayola	0.86	0.68
4	Dark Turquoise	0.67	0.60
5	Burnt Sienna	0.69	0.71
6	Cinnabar	0.80	0.63
7	Irresistible	0.72	0.61
8	Lapis Lazuli	0.66	0.55
9	Umber	0.55	0.30
10	Xiketic	0.47	0.59

No	Sample	CMYK	RYB
1	White	10	12
2	Lemon Glacier	14	7
3	Gold Crayola	20	15
4	Dark Turquoise	13	6
5	Burnt Sienna	16	17
6	Cinnabar	19	9
7	Irresistible	18	8
8	Lapis Lazuli	11	4
9	Umber	3	1
10	Xiketic	2	5

No	Sample	CMYK	RYB
1	White	6	5.5
2	Lemon Glacier	9.5	15
3	Gold Crayola	3	9.5
4	Dark Turquoise	7.5	12.5
5	Burnt Sienna	5.5	9.5
6	Cinnabar	5	15
7	Irresistible	3.5	16
8	Lapis Lazuli	10.5	13
9	Umber	10.5	18.5
10	Xiketic	16.5	18

Figure 9. Comparison of the CMYK and RYB samples based on CCT and thermal comfort points for hot and cold climates.

Although visual and thermal comforts involve albedo in their evaluations, they evaluate it from distinct perspectives. Visual comfort examines how much light is reflected by a surface to enhance illumination, whereas thermal comfort considers how much light is absorbed by the surface, impacting the radiant temperature or heat emitted. A lower albedo value corresponds to higher light absorption and subsequently a warmer room temperature. Similarly to the CCT analysis, the albedo results are varied and do not demonstrate a clear linear correlation. However, RYB samples tend to have lower albedo values than CMYK samples, indicating higher light absorption by the RYB surfaces. In this study, the implication of higher absorption is discussed in relation to thermal comfort scoring for hot and cold climate scenarios (Figure 9), rather than as a direct measurement of real room air temperature.

Figure 9 shows that the measured CCT values are relatively similar between CMYK and RYB samples, with only small variations. This suggests that, under the same LED source and geometry, surface color changes do not substantially shift the measured CCT. A slightly higher CCT in CMYK samples may contribute to a cooler visual impression, whereas lower CCT is commonly associated with a warmer visual impression.

In terms of absorption potential, lower albedo implies higher light absorption under identical incident lighting, which may increase the potential for radiative heating at the surface level. Nevertheless, this study did not measure air temperature, mean radiant temperature, air speed, or operative temperature, nor did it perform a heat-balance model. Therefore, we do not claim that specific color samples increase or decrease actual room temperature or that they deliver definitive thermal comfort outcomes. Instead, the results are presented as comparative proxy indicators of absorption tendency (albedo) and perceptual cues (CCT), which require validation through standard thermal comfort measurements and/or modeling [33,57]. Because the setup is a miniature enclosure with a single LED source, the reported thermal-related trends are proxy-based and do not substitute for

standardized thermal comfort evaluation, which requires operative temperature/MRT and airflow assessment [33,57].

Under the fixed lamp type, lamp position, and measurement geometry used in this experiment, the CMYK samples produced slightly higher CCT values than the RYB samples (Figure 9), indicating a marginally cooler appearance of the reflected light. The RYB samples also tended to show lower apparent albedo proxy values, consistent with a higher absorption tendency within the tested configuration, which aligns with the thermal-intent scoring trends reported for the hot- and cold-climate assumptions.

3.2.3. Plant-Supportive Lighting (Estimated PPFD)

The PPFD value graph shows a linear relationship between color and PPFD (Figure 10). As the RGB value of a color increases, its corresponding PPFD value also increases. The comparison showed that CMYK color samples consistently yielded higher PPFD values than that by RYB samples. This difference could be attributed to the higher illuminance values produced by the CMYK samples, as the PPFD values are directly influenced by illuminance. The key takeaway from this graph is that in terms of lighting, plants in rooms utilizing printed coloring techniques (CMYK) tend to perform better in photosynthesis, producing more oxygen, compared with those in rooms with painted coloring techniques (RYB).

No	Sample	CMYK	RYB
1	White	23.06	20.68
2	Lemon Glacier	20.03	17.27
3	Gold Crayola	18.97	16.66
4	Dark Turquoise	18.77	15.18
5	Burnt Sienna	17.82	14.06
6	Cinnabar	16.63	12.65
7	Irresistible	15.72	11.6
8	Lapis Lazuli	14.94	9.46
9	Umber	14.58	7.76
10	Xiketic	13.46	6.88

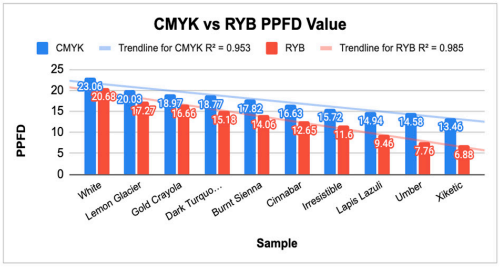


Figure 10. Comparison of the CMYK and RYB samples based on PPFD values.

3.3. Result Application

This section explains how to apply the Recommended Indoor Color Diagram (Figure 11) as a preliminary decision-support tool derived from the controlled experimental configuration in this study. To shortlist colors for a given scenario, the user answers the following questions:

- What activities will be conducted in the room?
- Is the room intended for office or residential use?
- Is the room located in a hot or cold climate?
- Are there any plants in the room?

Based on these inputs, Figure 11 maps the relative trends of the tested indicators (illuminance, RGB-derived reflectance proxy/albedo, CCT, and estimated PPFD) under fixed lighting and geometry. The diagram organizes recommendations into Groups A through E by activity type and provides candidate color shortlists by coloring technique (CMYK printed surfaces and RYB painted surfaces) and surface type (walls, ceilings, floors, or furniture).

To illustrate the practical usage of Figure 11, the following case examples are provided with explicit traceability from inputs to outputs. The cases were selected to represent contrasting combinations of (i) activity group, (ii) space function (office or residential), (iii) climate category (hot or cold), and (iv) plant presence. For each case, the input assumptions are stated clearly, the corresponding branch of Figure 11 is identified, and the resulting shortlist is reported accordingly. When an input is unknown (for example, plant presence), it is labeled as a scenario assumption for demonstration purposes.

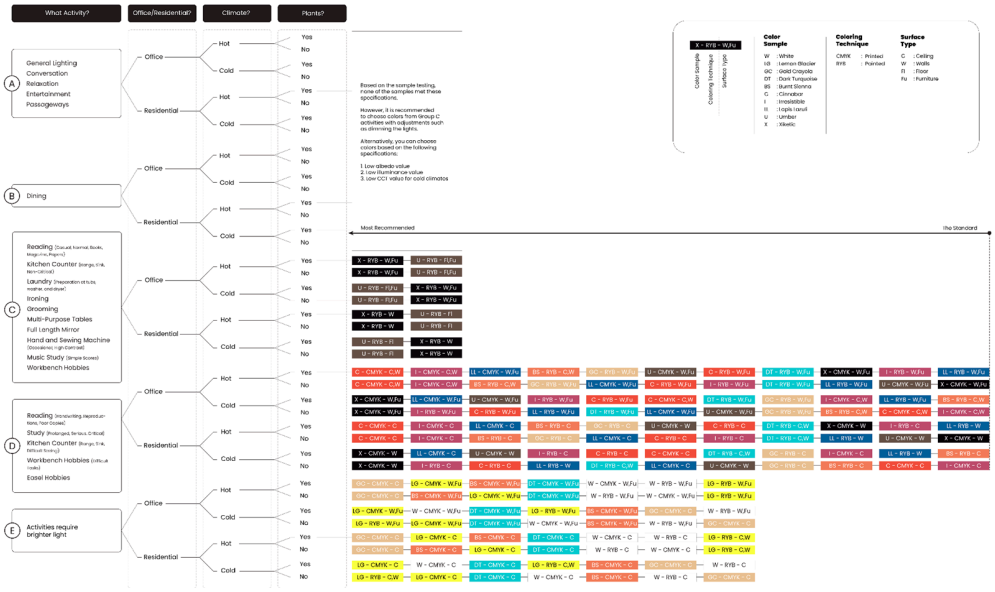


Figure 11. Preliminary indoor color shortlisting diagram based on user requirements (activity, climate, plant presence, and surface type) under the controlled experimental conditions of this study.

3.3.1. Case Example 1

To enhance tourism appeal and introduce local Balinese SME products to international tourists, a resort on the beach of Bali is launching a special program called a creative class. This creative class aims to teach the methods of making traditional Balinese handicrafts, guided directly by local artisans from the surrounding resort area. The program is planned to be held periodically using one of the rooms in the resort. The room will be decorated with a tropical concept characterized by many ornamental plants placed in every corner of the room.

Case inputs: Activity group = D (Workbench hobbies); Space function = residential (resort room); Climate = hot; Plant presence = yes.

Flowchart traceability: Figure 11 branch: Group D → residential → hot climate → plants present.

Output interpretation: The shortlist reflects relative trends under the tested setup; project-specific validation is recommended.

Based on this data, the recommended results are as follows (Table 2):

Table 2. Color Recommendations for Case Example 1.

No	Sample	Color Code	Coloring Technique	Surface Type
1	Cinnabar CMYK	(0%, 71%, 77%, 11%)	Printed (wallpaper/vinyl)	Ceiling
2	Irresistible CMYK	(0%, 62%, 40%, 30%)	Printed (wallpaper/vinyl)	Ceiling
3	Lapis Lazuli CMYK	(76%, 38%, 0%, 39%)	Printed (wallpaper/vinyl)	Ceiling
4	Burnt Sienna RYB	(233, 126, 81)	Painted	Ceiling
5	Gold Crayola RYB	(209, 230, 138)	Painted	Ceiling
6	Umber CMYK	(0%, 18%, 28%, 61%)	Printed (wallpaper/vinyl)	Walls
7	Cinnabar RYB	(227, 67, 52)	Painted	Ceiling
8	Dark Turquoise RYB	(0, 104, 209)	Painted	Ceiling, Walls
9	Xiketic CMYK	(20%, 87%, 0%, 94%)	Printed (wallpaper/vinyl)	Walls
10	Irresistible RYB	(179, 68, 108)	Painted	Ceiling
11	Lapis Lazuli RYB	(38, 77, 156)	Painted	Walls

1. What activities will be conducted in the room?

   Answer: Making handicrafts (Activity Group D: Workbench Hobbies)

2. Is the room intended for office or residential use?

   Answer: Resort (residential)

3. Is the room located in a hot or cold climate?

   Answer: Beachside Bali (hot climate)

4. Are there any plants in the room?

   Answer: Many ornamental plants (there are plants)

3.3.2. Case Example 2

"The Center for Volcanology and Geological Hazard Mitigation (PVMBG) is a government agency under the Geological Agency, one of whose functions is to monitor volcanoes. One of the active volcanoes monitored by PVMBG is Mount Gamalama, located in North Maluku Province. The geographical location of Mount Gamalama, which is quite isolated, makes PVMBG plan to build a semi-permanent research post that will function as a center for sample analysis and a close observation point of Mount Gamalama. The research post will be built next to the climbing post 3 at an altitude of 1343 m above sea level. Various research tools will be placed in this post so that rock analysis from Mount Gamalama can be carried out directly without having to wait for samples to be sent to another research station which is very far away and would take a long time."

Based on the above description, the following information is obtained:

1. What activities will be conducted in the room?

   Answer: Rock analysis (Activity Group E: work requiring very bright rooms)

2. Is the room intended for office or residential use?

   Answer: Research post (office)

3. Is the room located in a hot or cold climate?

   Answer: Mount Gamalama, altitude 1343 m above the sea level (cold climate)

4. Are there any plants in the room?

   Answer: No information (assumed none)

Based on this data, the recommended results are as follows (Table 3):

Table 3. Color Recommendations for Case Example 2.

No	Sample	Color Code	Coloring Technique	Surface Type
1	Lemon Glacier RYB	(0, 255, 2)	Painted	Walls, Furniture
2	Lemon Glacier CMYK	(0%, 16%, 100%, 0%)	Printed (wallpaper/vinyl)	Walls, Furniture
3	Dark Turquoise CMYK	(100%, 1%, 0%, 18%)	Printed (wallpaper/vinyl)	Walls, Furniture
4	White CMYK	(0%, 0%, 0%, 0%)	Printed (wallpaper/vinyl)	Walls, Furniture
5	Burnt Sienna CMYK	(0%, 50%, 65%, 9%)	Printed (wallpaper/vinyl)	Walls, Furniture
6	White RYB	(255, 255, 255)	Painted	Walls, Furniture
7	Gold Crayola CMYK	(0%, 17%, 40%, 10%)	Printed (wallpaper/vinyl)	Ceiling

3.3.3. Case Example 3

"Disneyland Japan is opening a new recreational attraction during the winter season with the theme 'A Whole New World.' This attraction is an opera house that will feature various events such as musical dramas and performances from one of Disney's famous

animations, Aladdin. The opera house will have a capacity of 500 seats. Three performances will be held daily, each lasting 1.5 h."

Based on the above description, the following information is obtained:

1. What activities will be conducted in the room?

   Answer: Musical dramas and performances (Activity Group A: entertainment)

2. Is the room intended for office or residential use?

   Answer: Neither office nor residential

3. Is the room located in a hot or cold climate?

   Answer: Japan in winter (cold climate)

4. Are there any plants in the room?

   Answer: No

Based on these data, the activity conducted is musical drama, categorized under activity Group A (entertainment). According to the recommendation diagram, no sample met the criterion. However, it is recommended to use colors from activity Group C with dimmed lighting. Another approach is to find colors that meet specific specifications, such as dark colors with low albedo, illuminance, and CCT values.

4. Conclusions

The aim of this study is to assess the performance of the room surface colors in terms of indoor environmental quality, with particular emphasis on visual comfort, thermal comfort, and the plant-related pathway of indoor air quality. In this study, the methodological approach is a controlled miniature indoor model with varying surface colors under fixed measurement conditions. In this context, the illuminance and correlated color temperature are recorded using the Light Spectrum Pro EVO and Opple Light Master, and the data are processed using Google Sheets. The outcome of the study reveals that the optimal choice of surface colors is context-dependent and varies with the requirements of the room and the targeted indoor environmental quality. Notably, the novelty of this study is the provision of a practical and replicable process that converts interior surface color choices into quantified and comparable measures under controlled conditions, with a clear distinction between directly measured lighting variables and interpretations, along with the limitations of the transferability of the data to actual rooms.

Key findings are summarized as follows:

- Visual Comfort: The performance of color is not entirely based on higher or lower levels of illuminance and albedo values, but rather on the alignment with appropriate levels of lighting conditions for the intended activities. Gold Crayola (paint technique) can be used for activities that require higher levels of light, such as reading and sewing, and should be applied on walls and furniture in offices and on ceilings in homes.
- Thermal Comfort; For hot climates, colors with higher levels of albedo values support the thermal comfort condition by reflecting higher levels of light, with Gold Crayola CMYK scoring the highest among all colors in this category. For cold climates, the low levels of albedo combined with low levels of correlated color temperature support the thermal comfort condition, with Umber RYB scoring the highest.
- Estimated PPFD; The lighting conditions that support plant activities, as indicated by photosynthetic photon flux density calculated from the levels of illuminance, were highest for White CMYK (23.06 $\mu mol/m^2/s$), indicating higher support for photosynthesis-driven plant activities in the setup.

In summary, the results verify that the suitability of colors is dependent on room purpose, climate-oriented thermal intention, and plant-rich interior conditions. Color

recommendations for various conditions are presented in Figure 11. Differences were also found between the coloring technique of the printed surface (CMYK) and the paint technique (RYB). Surfaces produced by the CMYK technique showed brighter lighting impressions, as well as higher plant-supportive lighting indicators, while surfaces produced by the RYB technique showed darker lighting impressions under the same lamp condition.

The current study adopted a controlled and scaled-down form of a screening test. The control over lighting is restricted to a basic form of an LED lamp with fixed lamp positions and fixed geometry for measurements, which may allow for consistency in cross-color comparisons but may not allow for generalization to other lamps and scaled-up rooms. Moreover, the scaled-down model and the use of device readings may allow for comparative evaluation in the current configuration; thus, the current illuminance, correlated color temperature, and RGB-derived reflectance proxy may not be taken as absolute predictors for scaled-up configurations in terms of visual comfort, thermal comfort, and air quality. The current test may only consider 20 color samples in the experiment (10 CMYK and 10 RYB). It is recommended that future studies consider increasing the sample pool and validating the current results in scaled-up rooms.

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Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author/s.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

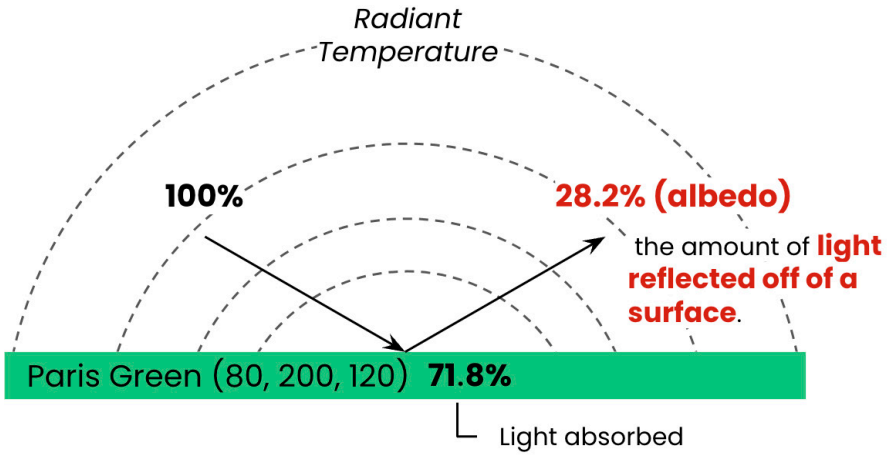


Figure A1. Relationship Between Albedo, Light Absorption, and Radiant Temperature.

Table A1. Color Sample Conversion for CMYK and RYB Models.

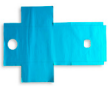
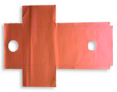
No	Albedo Rank	Color Name	RGB Code	CMYK Sample (Printed) Converted Code	CMYK Sample (Printed) Sample	RYB Sample (Painted) Converted Code	RYB Sample (Painted) Sample
1	1	White	(255, 255, 255)	(0%, 0%, 0%, 0%)		(255, 255, 255)	
2	107	Lemon Glacier	(253, 255, 000)	(0%, 16%, 100%, 0%)		(0, 255, 2)	
3	213	Gold Crayola	(230, 190, 138)	(0%, 17%, 40%, 10%)		(209, 230, 138)	
4	319	Dark Turquoise	(000, 206, 209)	(100%, 1%, 0%, 18%)		(0, 104, 209)	
5	425	Burnt Sienna	(233, 116, 081)	(0%, 50%, 65%, 9%)		(233, 126, 81)	
6	531	Cinnabar	(227, 066, 052)	(0%, 71%, 77%, 11%)		(227, 67, 52)	
7	637	Irresistible	(179, 068, 108)	(0%, 62%, 40%, 30%)		(179, 68, 108)	
8	743	Lapis Lazuli	(038, 097, 156)	(76%, 38%, 0%, 39%)		(38, 77, 156)	
9	849	Umber	(099, 081, 071)	(0%, 18%, 28%, 61%)		(99, 87, 71)	
10	955	Xiketic	(012, 002, 015)	(20%, 87%, 0%, 94%)		(12, 2, 15)	

Table A2. Detected Illuminance Value on LSP EVO and OLM Device Comparison on CMYK and RYB Samples.

No	Samples	Illuminance	Group
1	White	1338	>1000 Lux
2	Lemon Glacier	1162	>1000 Lux
3	Gold Crayola	1101	>1000 Lux
4	Dark Turquoise	1089	>1000 Lux
5	Burnt Sienna	1034	>1000 Lux
6	Cinnabar	965	D
7	Irresistible	912	D
8	Lapis Lazuli	867	D
9	Umber	846	D
10	Xiketic	781	D
1	White	1200	>1000 Lux
2	Lemon Glacier	1002	>1000 Lux
3	Gold Crayola	967	D
4	Dark Turquoise	881	D
5	Burnt Sienna	816	D
6	Cinnabar	734	D
7	Irresistible	673	D
8	Lapis Lazuli	549	D
9	Umber	450	C
10	Xiketic	399	C

Table A3. Thermal Comfort Point Ranking for Each Color Sample in CMYK and RYB Models in a Hot Climate.

Rank	Samples	Albedo Points	CCT Points	Avg
1	Gold Crayola CMYK	20	*NS*	20
2	Cinnabar CMYK	19	*NS*	19
3	Irresistible CMYK	18	*NS*	18
4	Burnt Sienna RYB	17	*NS*	17
5	Burnt Sienna CMYK	16	*NS*	16
6	Gold Crayola RYB	15	*NS*	15
7	Lemon Glacier CMYK	14	*NS*	14
8	Dark Turquoise CMYK	13	*NS*	13
9	White RYB	12	*NS*	12
10	Lapis Lazuli CMYK	11	*NS*	11
11	White CMYK	10	*NS*	10
12	Cinnabar RYB	9	*NS*	9
13	Irresistible RYB	8	*NS*	8
14	Lemon Glacier RYB	7	*NS*	7
15	Dark Turquoise RYB	6	*NS*	6
16	Xiketic RYB	5	*NS*	5
17	Lapis Lazuli RYB	4	*NS*	4
18	Umber CMYK	3	*NS*	3
19	Xiketic CMYK	2	*NS*	2
20	Umber RYB	1	*NS*	1

NS: Not Significant.

Table A4. Thermal Comfort Proxy Ranking for Each Color Sample in CMYK and RYB Models in a Cold Climate.

Rank	Samples	Albedo Points	CCT Points	Avg
1	Umber RYB	20	17	18.5
2	Xiketic RYB	16	20	18
3	Xiketic CMYK	19	14	16.5
4	Irresistible RYB	13	19	16
5	Lemon Glacier RYB	14	16	15
6	Cinnabar RYB	12	18	15
7	Lapis Lazuli RYB	17	9	13
8	Dark Turquoise RYB	15	10	12.5
9	Lapis Lazuli CMYK	10	11	10.5
10	Umber CMYK	18	3	10.5
11	Lemon Glacier CMYK	7	12	9.5
12	Gold Crayola RYB	6	13	9.5
13	Burnt Sienna RYB	4	15	9.5
14	Dark Turquoise CMYK	8	7	7.5
15	White CMYK	11	1	6
16	Burnt Sienna CMYK	5	6	5.5
17	White RYB	9	2	5.5
18	Cinnabar CMYK	2	8	5
19	Irresistible CMYK	3	4	3.5
20	Gold Crayola CMYK	1	5	3

Table A5. PPFD Value Ranking and Suitability for Low Shade and High Shade Plants.

Rank	Samples	Value	Low Shade Plant	High Shade Plant	Max
1	White CMYK	23.06	x	x	x
2	White RYB	20.68	x	x	x
3	Lemon Glacier CMYK	20.03	x	x	x
4	Gold Crayola CMYK	18.97	x	x	x
5	Dark Turquoise CMYK	18.77	x	x	x
6	Burnt Sienna CMYK	17.82	x	x	x
7	Lemon Glacier RYB	17.27	x	x	x
8	Gold Crayola RYB	16.66	x	x	x
9	Cinnabar CMYK	16.63	x	x	x
10	Irresistible CMYK	15.72	x	x	x
11	Dark Turquoise RYB	15.18	x	x	x
12	Lapis Lazuli CMYK	14.94	x	x	x
13	Umber CMYK	14.58	x	x	x
14	Burnt Sienna RYB	14.06	x	x	x
15	Xiketic CMYK	13.46	x	x	x
16	Cinnabar RYB	12.65	x	x	x
17	Irresistible RYB	11.60	x	x	x
18	Lapis Lazuli RYB	9.46	x	x	x
19	Umber RYB	7.76	x	x	x
20	Xiketic RYB	6.88	x	x	x

Table A6. PPFD Value Ranking and Points Assignment.

Rank	Samples	Value	Point
1	White CMYK	23.06	20
2	White RYB	20.68	19
3	Lemon Glacier CMYK	20.03	18
4	Gold Crayola CMYK	18.97	17
5	Dark Turquoise CMYK	18.77	16
6	Burnt Sienna CMYK	17.82	15
7	Lemon Glacier RYB	17.27	14
8	Gold Crayola RYB	16.66	13
9	Cinnabar CMYK	16.63	12
10	Irresistible CMYK	15.72	11
11	Dark Turquoise RYB	15.18	10
12	Lapis Lazuli CMYK	14.94	9
13	Umber CMYK	14.58	8
14	Burnt Sienna RYB	14.06	7
15	Xiketic CMYK	13.46	6
16	Cinnabar RYB	12.65	5
17	Irresistible RYB	11.60	4
18	Lapis Lazuli RYB	9.46	3
19	Umber RYB	7.76	2
20	Xiketic RYB	6.88	1

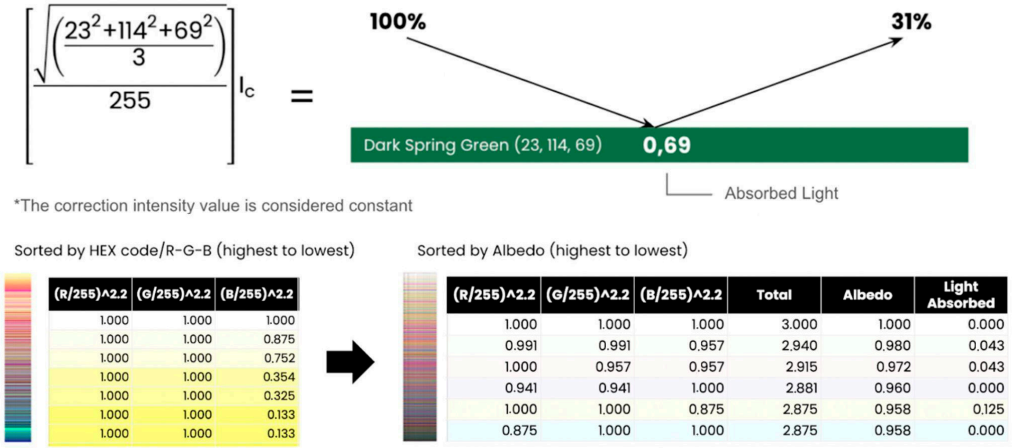
Hex | Decimal | Fraction

name	hexCode	redHex	greenHex	blueHex	redDecimal	greenDecimal	blueDecimal	redFraction	greenFraction	blueFraction
Baker-Miller pink	#FF91AF	FF	91	AF	255	145	175	1	57	69
Bright yellow (Crayola)	#FFAA1D	FF	AA	1D	255	170	29	1	67	11
Amber	#FFBF00	FF	BF	00	255	191	0	1	75	0
Amber (SAE/ECE)	#FF7E00	FF	7E	00	255	126	0	1	49	0
Atomic tangerine	#FF9966	FF	99	66	255	153	102	1	6	4
Bisque	#FFE4C4	FF	E4	C4	255	228	196	1	89	77
Candy apple red	#FF0800	FF	08	00	255	8	0	1	3	0
Baby powder	#FEFEFA	FE	FE	FA	254	254	250	1	1	98
Coquelicot	#FF3800	FF	38	00	255	56	0	1	22	0
Blanched almond	#FFEBCD	FF	EB	CD	255	235	205	1	92	8

+ Color
+ Sorted by RGB code

name	hexCode	redHex	greenHex	blueHex	redDecimal	greenDecima	blueDecima	redFraction
White	#FFFFFF	FF	FF	FF	255	255	255	1
Ivory	#FFFFF0	FF	FF	F0	255	255	240	1
Light yellow	#FFFFE0	FF	FF	E0	255	255	224	1
Lemon yellow (Crayol	#FFFF9F	FF	FF	9F	255	255	159	1
Canary	#FFFF99	FF	FF	99	255	255	153	1
Laser lemon	#FFFF66	FF	FF	66	255	255	102	1
Unmellow yellow	#FFFF66	FF	FF	66	255	255	102	1
Yellow	#FFFF00	FF	FF	00	255	255	0	1

Figure A2. Processed Color Database.



(R/255)^2.2	(G/255)^2.2	(B/255)^2.2
1.000	1.000	1.000
1.000	1.000	0.875
1.000	1.000	0.752
1.000	1.000	0.354
1.000	1.000	0.325
1.000	1.000	0.133
1.000	1.000	0.133

(R/255)^2.2	(G/255)^2.2	(B/255)^2.2	Total	Albedo	Light Absorbed
1.000	1.000	1.000	3.000	1.000	0.000
0.991	0.991	0.957	2.940	0.980	0.043
1.000	0.957	0.957	2.915	0.972	0.043
0.941	0.941	1.000	2.881	0.960	0.000
1.000	1.000	0.875	2.875	0.958	0.125
0.875	1.000	1.000	2.875	0.958	0.000

Figure A3. Albedo Calculation for Dark Spring Green with RGB (23, 114, 69).



Figure A4. Comparison of Data Collection Methods Using Light Spectrum Pro EVO application and Opple Light Master.

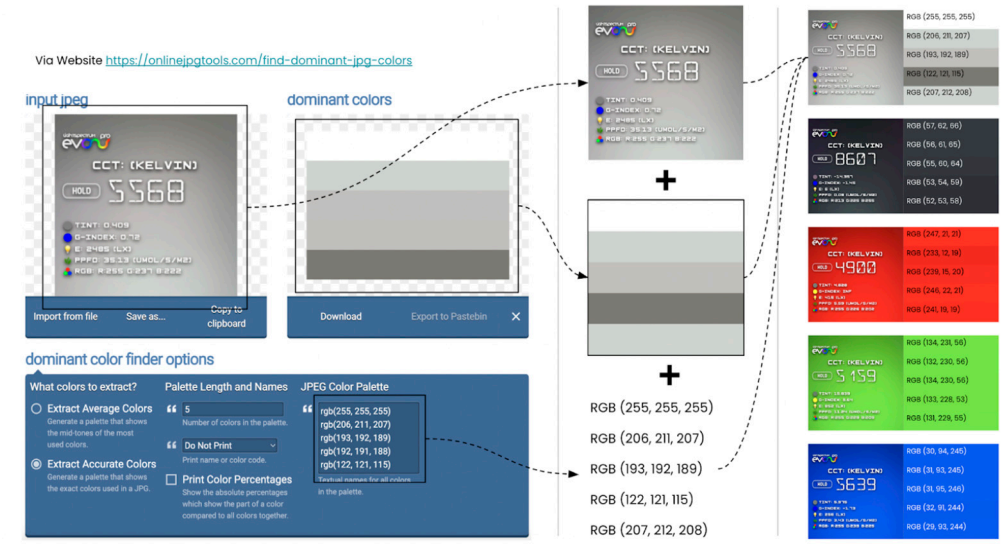


Figure A5. Identifying Dominant RGB Values Using the Online JPEG Tool.

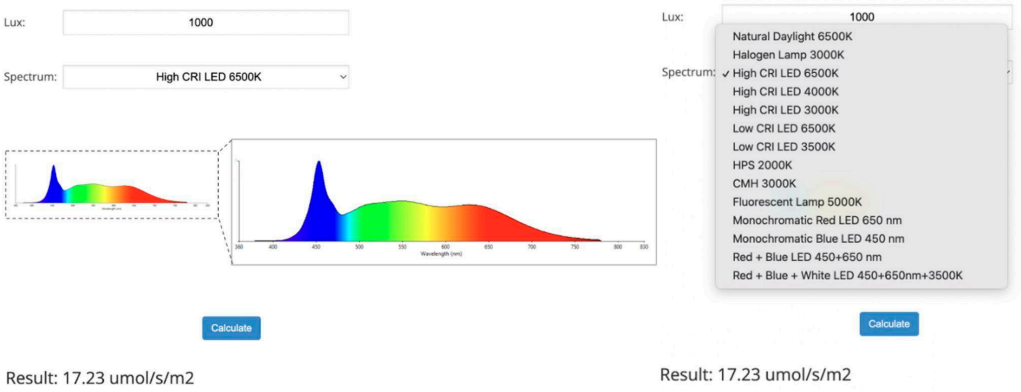


Figure A6. Calculation of Photosynthetic Photon Flux Density (PPFD) Using the Lux to PPFD Online Calculator.

Table A7. Detected RGB on LSP EVO and OLM Device Comparison.

Detected RGB on LSP EVO	Accuracy Classification: Based on Detected Code Discrepancies					Checking
	0–20%	21–40%	41–60%	61–80%	81–100%	
CMYK LSP EVO	12	4	5	4	5	30
RYB LSP EVO	12	2	7	5	4	30
Total	24	6	12	9	9	60
%	40	10	20	15	15	100
Point	2	1	0	−1	−2	
Total Point	80	10	0	−15	−30	45
Detected RGB on OLM Device	Accuracy Classification: Based on Detected Code Discrepancies					Checking
	0–20%	21–40%	41–60%	61–80%	81–100%	
CMYK OLM	10	17	2	1	0	30
RYB OLM	15	12	3	0	0	30
Total	25	29	5	1	0	60
(%)	42	48	8	2	0	100
Point	2	1	0	−1	−2	
Total Point	83	48	0	−2	0	130

Table A8. Accuracy Comparison.

Value	LSP EVO	OLM Device
RGB	45	130
Illuminance CMYK	0.651	0.953
Illuminance RYB	0.605	0.985
CCT CMYK	0.052	0.099
CCT RYB	0.279	0.447
PPFD CMYK	0.645	0.953
PPFD RYB	0.624	0.985

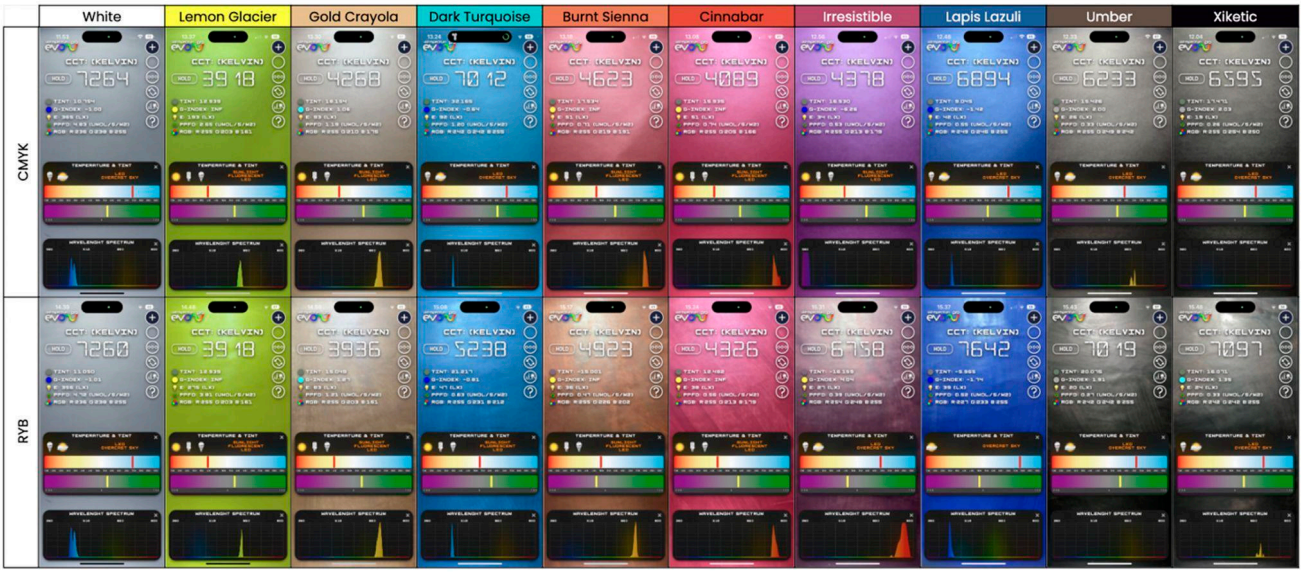


Figure A7. Documentation of RGB, Illuminance, CCT, and PPFD Data Capture Using the Light Spectrum Pro EVO Application.



Figure A8. Documentation of RGB Data Retrieval Using the Dominant RGB Detection Website.

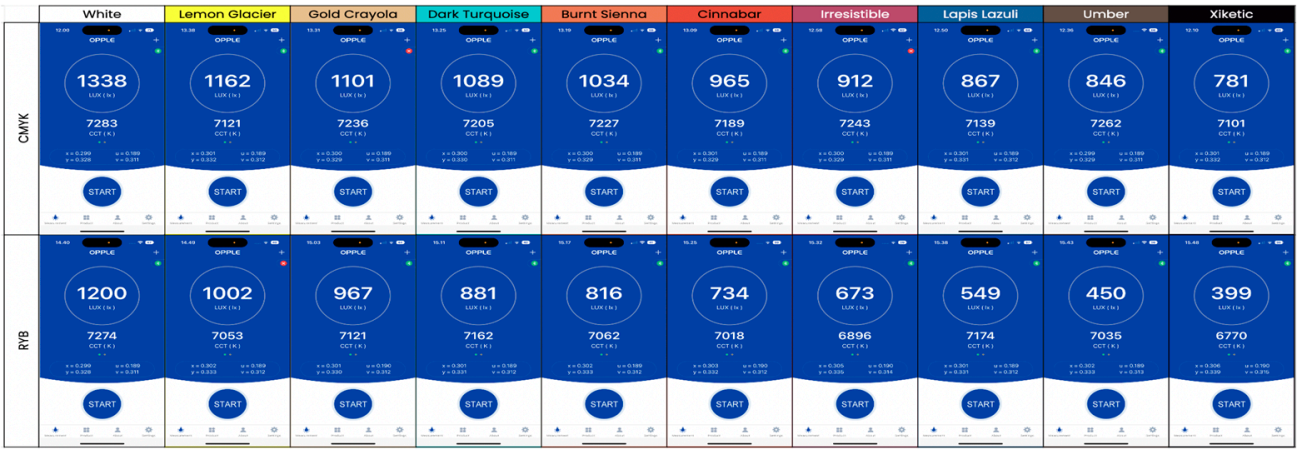


Figure A9. Documentation of Illuminance and CCT Data Capture Using the Opple Light Master Device.

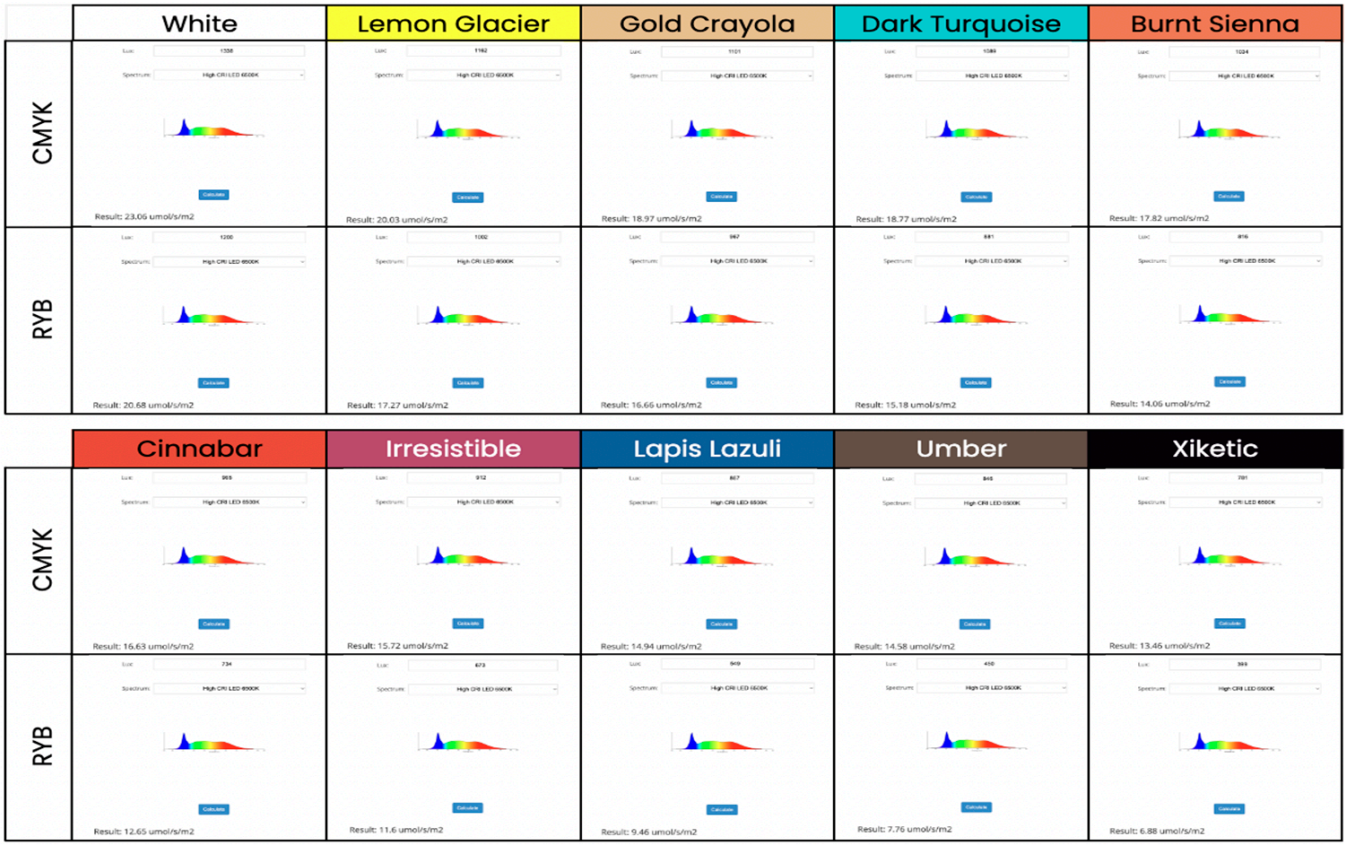


Figure A10. Documentation of PPFD Data Retrieval Using the PPFD Calculation Website.

CMYK Sample **Albedo** Calculation Based on the **LightSpectrumPro Evo Application**

No	Sample	R	G	B	R²	G²	B²	Total	/3	√	/255	Albedo
1	Xiketic	255	254	250	65,025	64,516	62,500	192,041	64,014	253	0.992	0.992
2	Lapis Lazuli	249	246	255	62,001	60,516	65,025	187,542	62,514	250	0.981	0.981
3	Umber	255	249	242	65,025	62,001	58,564	185,590	61,863	249	0.975	0.975
4	Dark Turquoise	242	242	255	58,564	58,564	65,025	182,153	60,718	246	0.966	0.966
5	White	236	238	255	55,696	56,644	65,025	177,365	59,122	243	0.954	0.954
6	Burnt Sienna	255	219	191	65,025	47,961	36,481	149,467	49,822	223	0.875	0.875
7	Irresistible	255	213	179	65,025	45,369	32,041	142,435	47,478	218	0.854	0.854
8	Gold Crayola	255	210	175	65,025	44,100	30,625	139,750	46,583	216	0.846	0.846
9	Cinnabar	255	205	166	65,025	42,025	27,556	134,606	44,869	212	0.831	0.831
10	Lemon Glacier	255	203	161	65,025	41,209	25,921	132,155	44,052	210	0.823	0.823

CMYK Sample **Albedo** Calculation Based on the **Website Color Generator**

No	Sample	R	G	B	R²	G²	B²	Total	/3	√	/255	Albedo
1	Gold Crayola	216	222	222	46,656	49,284	49,284	145,224	48,408	220	0.863	0.863
2	Cinnabar	243	150	208	59,049	22,500	43,264	124,813	41,604	204	0.800	0.800
3	Irresistible	184	134	221	33,856	17,956	48,841	100,653	33,551	183	0.718	0.718
4	Burnt Sienna	217	140	159	47,089	19,600	25,281	91,970	30,657	175	0.687	0.687
5	Lemon Glacier	171	220	99	29,241	48,400	9801	87,442	29,147	171	0.670	0.670
6	Dark Turquoise	91	172	221	8281	29,584	48,841	86,706	28,902	170	0.667	0.667
7	Lapis Lazuli	103	151	227	10,609	22,801	51,529	84,939	28,313	168	0.660	0.660
8	White	153	164	170	23,409	26,896	28,900	79,205	26,402	162	0.637	0.637
9	Umber	144	140	135	20,736	19,600	18,225	58,561	19,520	140	0.548	0.548
10	Xiketic	122	120	115	14,884	14,400	13,225	42,509	14,170	119	0.467	0.467

RYB Sample **Albedo** Calculation Based on the **LightSpectrumPro Evo Application**

No	Sample	R	G	B	R²	G²	B²	Total	/3	√	/255	Albedo
1	Irresistible	254	248	255	64,516	61,504	65,025	191,045	63,682	252	0.990	0.990
2	Umber	242	242	255	58,564	58,564	65,025	182,153	60,718	246	0.966	0.966
3	Xiketic	242	242	255	58,564	58,564	65,025	182,153	60,718	246	0.966	0.966
4	White	236	238	255	55,696	56,644	65,025	177,365	59,122	243	0.954	0.954
5	Lapis Lazuli	227	233	255	51,529	54,289	65,025	170,843	56,948	239	0.936	0.936
6	Dark Turquoise	255	231	212	65,025	53,361	44,944	163,330	54,443	233	0.915	0.915
7	Burnt Sienna	255	226	202	65,025	51,076	40,804	156,905	52,302	229	0.897	0.897
8	Cinnabar	255	213	179	65,025	45,369	32,041	142,435	47,478	218	0.854	0.854
9	Lemon Glacier	255	203	161	65,025	41,209	25,921	132,155	44,052	210	0.823	0.823
10	Gold Crayola	255	203	161	65,025	41,209	25,921	132,155	44,052	210	0.823	0.823

RYB Sample **Albedo** Calculation Based on the **Website Color Generator**

No	Sample	R	G	B	R²	G²	B²	Total	/3	√	/255	Albedo
1	Burnt Sienna	212	175	151	44,944	30,625	22,801	98,370	32,790	181	0.710	0.710
2	Gold Crayola	185	172	159	34,225	29,584	25,281	89,090	29,697	172	0.676	0.676
3	White	161	170	177	25,921	28,900	31,329	86,150	28,717	169	0.665	0.665
4	Cinnabar	217	101	145	47,089	10,201	21,025	78,315	26,105	162	0.634	0.634
5	Irresistible	171	141	154	29,241	19,881	23,716	72,838	24,279	156	0.611	0.611
6	Lemon Glacier	165	201	52	27,225	40,401	2704	70,330	23,443	153	0.600	0.600
7	Dark Turquoise	67	146	211	4489	21,316	44,521	70,326	23,442	153	0.600	0.600
8	Xiketic	154	152	146	23,716	23,104	21,316	68,136	22,712	151	0.591	0.591
9	Lapis Lazuli	66	109	209	4356	11,881	43,681	59,918	19,973	141	0.554	0.554
10	Umber	78	79	75	6084	6241	5625	17,950	5983	77	0.303	0.303

Figure A11. RGB Albedo Calculation Table for Sample Results.

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